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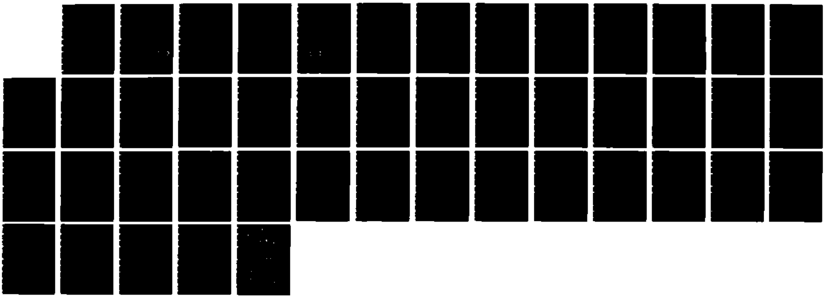

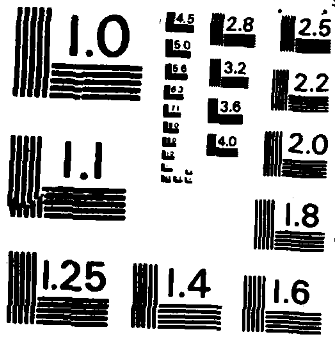
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AIRBORNE NAVIGATION REMOTE MAP READER EVALUATION

James C. Byrd
Intergrated Controls/Displays Branch
Avionics Systems Division
Directorate of Avionics Engineering

March 1986

Final Report for Period 1 September 1984 to 30 September 1985

Approved for Public Release; Distribution Unlimited

DEPUTY FOR ENGINEERING
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO, 45433-6503

NOTICE

This technical report has been reviewed and is approved for publication.

JAMES C. BYRD
Electronics Engineer
Integrated Controls & Displays Branch

JOHN W. PRICE, Chief
Avionics Systems Division
Directorate of Avionics Engineering

FOR THE COMMANDER

GARY L. LUDWIG
Technical Director
Directorate of Avionics Engineering

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The U.S. Air Force evaluated the Full-Color Remote Map Reader built by Thomson-CSF of France under the Foreign Weapons, Equipment, and Technology Evaluation program. The unit is used in a military aircraft to provide a moving map video display for the aircrew. Map data is contained in a 65-foot roll of 35mm film at 11.4:1 reduction, which allows approximately 550 sq. ft. of aeronautical charts of any standard scale to be stored in one cassette. The unit moves the film with microprocessor-controlled servo motors and performs scanning, rotation and zoom with a microprocessor-controlled flying spot scanner. It obtains navigation data from the aircraft MIL-STD-1553 data bus and presents video on a full-color, shadow-mask cathode ray tube. The evaluation determined that the moving map display is useful in several Air Force missions, and that the French map reader technology is roughly equivalent to devices recently developed in the U.S.

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PREFACE

This report documents the test and evaluation by the USAF of a moving-map generator built by Thomson CSF of France. The evaluation was conducted by the Aeronautical Systems Division,assisted by the 3246th Test Wing at Eglin AFB, Singer-Link, and Bendix. The report makes use of five figures taken from Thomson CSF and Hamilton Standard documents.

This project has provided experience and information on airborne moving-map systems and color display units which is being applied to a variety of projects at ASD.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

The US Air Force evaluated the French Full-Color Remote Map Reader (FCRMR) using funds from Program Element NO. 65111D entitled Foreign Weapons, Equipment, and Technology Evaluation (FWETE), DoD Mission Area 460, International Cooperative RDTE. Funds provided by Congress under this PE provide for technical and/or operational evaluation of friendly foreign nations' weapons systems and technologies to determine their potential use to DoD components. Beginning in FY 1980, Service activities in the FWETE Area, formerly conducted under PEs 65714A, 64793N, and 64736F, were combined under PE65111D in the Office of the Under Secretary of Defense Research and Engineering (OUSDRE). This program element, managed by the Director Defense Test and Evaluation (DDTE) in coordination with the Deputy USDRE, International Programs and Technology (IPT), is a part of the Directorate of Test and Evaluation, Defense Appropriation.

It directly supports the policy of the United States that equipment procured for use by personnel of the Armed Forces of the United States stationed in Europe under the terms of the North Atlantic Treaty be standardized or at least interoperative with other NATO equipment. In addition, the FWETE program provides potential for significant resource savings by avoiding unnecessary duplication in development.

The Integrated Controls and Displays Branch, Avionics Systems Division, Directorate of Avionics Engineering, Deputy for Engineering, of Aeronautical Systems Divisions (ASD/ENASI) was assigned to evaluate the French Full-Color Remote Map Reader (FCRMR or just RMR), called MERCATOR by the French, in 1982. The RMR provides a moving-map picture on a CRT display in the aircraft cockpit. Previous technology (see fig. 1) used a dedicated map display in the cockpit. The first-generation system, such as was used in the A-7 and HH-53, used a dedicated map projector/display in the cockpit. The second-generation system was used in the F-111D and F-18 and optically combined a CRT image (radar, TV, or symbology) with the projected map image. The RMR is the third-generation system. It eliminates most of the electromechanical parts as well as the high-powered projection lamp and large optics.

The RMR provides the pilot/navigator with a TV video display of his present position according to his selected primary navigation sensor (INS, GPS, etc.). The processor in the RMR converts the latitude/longitude numbers into a film position and provides a pictorial representation of aircraft location on a format similar to his current paper maps. The display can be in a track-up or north-up orientation. Various size/scale maps can be selected depending on the detail required and will automatically be presented at his present position.

.The French RMR uses a Flying Spot Scanner (FSS) to scan the film, and three color-indexed Photomultiplier Tubes (PMT) to generate a color video signal. The video signal can be presented on a color cockpit display, or on a monochrome display for a backup green map presentation. The intended military usage is for the air-to-ground mission as an aid in navigation, target and threat location, terrain-following and terrain-avoidance. Preproduction prototype units were flight-tested in the French Mirage 2000 in 1983 as part of a system known as ICARE.

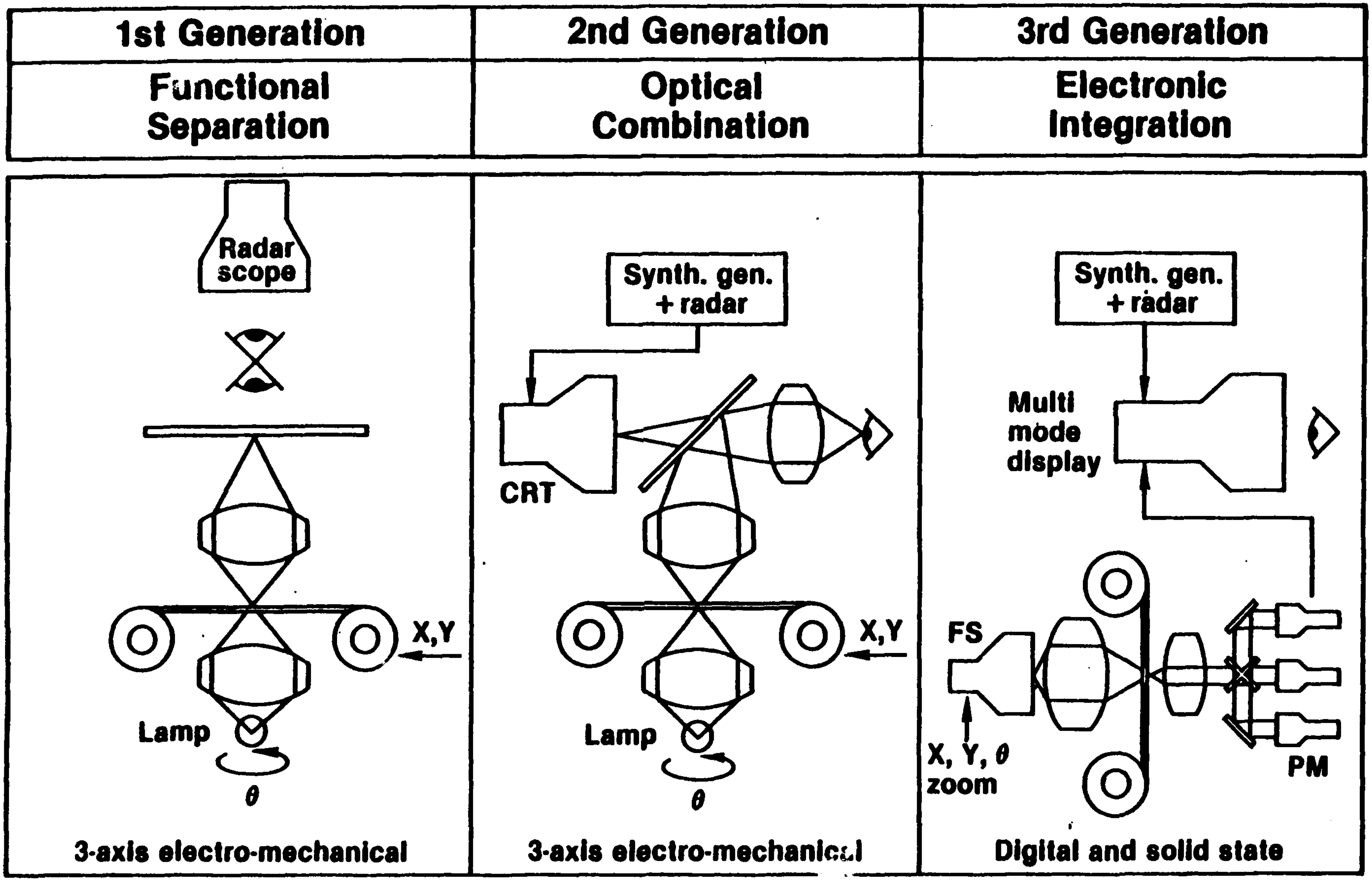


Fig. 1. Map Display Evolution

The original FWETE RMR proposal called for a quantity of three systems as originally installed in the Mirage 2000; this included three each RMRs, symbol generators, and color CRT display units. This proposal was expensive and did not represent a configuration which the USAF would procure or install in production. The program was restructured to procure two RMR units of a modified design which includes the power supply, MIL-STD-1553 data bus interface and symbology generator in a single unit. This consolidated the essential components from the French ICARE system into one unit so that if the test results were positive, the units could be purchased as is for U.S. production incorporation. This also allowed easier test installations.

The evaluation requires a full-color raster display to serve as the display media. Existing displays using shadow mask color CRTs are ideally suited to this task in most applications but have marginal brightness and contrast capabilities when used in the full, direct-sunshine environment of a fighter cockpit. A secondary goal of this evaluation was to assess the usefulness of shadow mask CRTs in this application and to determine if a real operational limitation exists.

The FCRMR program was expected to give the U.S. a look at the color RMR and color CRT technology/technique for replacing current projected map displays as quickly as possible. At about the same time that the FCRMR program was initiated, Bendix Corp., Flight Systems Division, in Teterboro NJ, was also developing an RMR. During the FWETE RMR program, and before the Thompson CSF design was licensed for sale in the United States, the Bendix RMR was chosen for the USAF HH-60 helicopter and the F-15E, and is being flight-tested on the HH-60 in 1985.

The contract with Thomson-CSF was negotiated in March 1983, and allowed 18 months for modification of the design and manufacture of the FCRMR units. Both units underwent acceptance testing in September 1984 and were shipped to WPAFB in October 1984. Laboratory and simulation tests were conducted between October 1984 and March 1985. The flight test was performed by the 3246 Test Wing at Eglin AFB, Florida and occurred between 30 May 1985 and 19 September 1985

The U.S. and other countries are also looking into digital-data-based map displays, however, availability for production installations before 1988 or 1990 is highly questionable. A large-enough airborne mass memory device and the detailed digital data base from the Defense Mapping Agency is not available in the near term.

2.0 DESIGN/TECHNOLOGY

The RMR block diagram is shown in figure 2. Each major function is described here to indicate the technology used, with it's inherent performance advantages or limitations. The outline and mechanical drawings of the RMR and cassette are shown in figures 3 and 4.

2.1 SCANNER

The critical component in the RMR is the film scanning and sensing device. The French RMR, as well as the recently developed Bendix (U.S.) RMR, use a Flying Spot Scanner (FSS) for this function. FSS technology has been in use for years in commercial applications, such as film scanners which convert 35mm film movies to TV video format for broadcast. The FSS consists of a Cathode Ray Tube (CRT), optics, color separator, light sensors (Photomultiplier tubes or PMT) and the associated power supplies, drive electronics, and signal amplifiers. The flying spot scanner is driven under microprocessor control. This provides flexibility in raster format, size, position and orientation. For example, it is possible to change from European format (625-line, 25-frame) video to U.S. format (525-line, 30-frame) video by changing only the microprocessor's program. The microprocessor uses desired scale factors, offsets, rotations, etc., to calculate desired deflection voltages in the digital realm; these numbers are then applied to Digital to Analog converters (DAC) and amplifiers to drive the FSS in the analog realm. The ability to move the scanned area across the film and change it's rotation electronically eliminates two of the three servo systems used in the previous map system.

Use of one of the new Charge Coupled Device (CCD) video sensors has also been considered for RMR applications, since they are compact and completely solid state. However, the CCD camera's format is rigidly fixed by the sensor array, so use of the CCD implies use of the mechanically complex X, Y and rotation servo system.

2.2 FILM

The "data base" for the RMR is a roll of 35 mm (1.37 inches) wide film, 65 feet long, containing photo-reduced images (11.4:1 reduction of standard paper maps). Defense Mapping Agency Aerospace Center (DMAAC) in St. Louis, Missouri, makes this film.

The process is similar to that used in the past to make filmstrips for the A-7 and F-18 map projectors. It cons s of cutting up the paper charts and glueing the pieces onto a sheet of st ole base material according to accurately drawn latitude and longitude grids, then photographing this "mosaic" in strips on the film. Each different geographic area or different scale chart is called a block, and the RMR is programmed to handle filmstrips containing up to 15 blocks. The RMR is compatible with the seven map scales which are in common use in the U.S., but for aircraft applications, only five will normally be used, and all of these scales will not generally be on a filmstrip for a specific aircraft. The details of the filmstrip layout and geodetic system are contained in specification PS/IDA/150, Remote Map Reader Navigational Filmstrips.

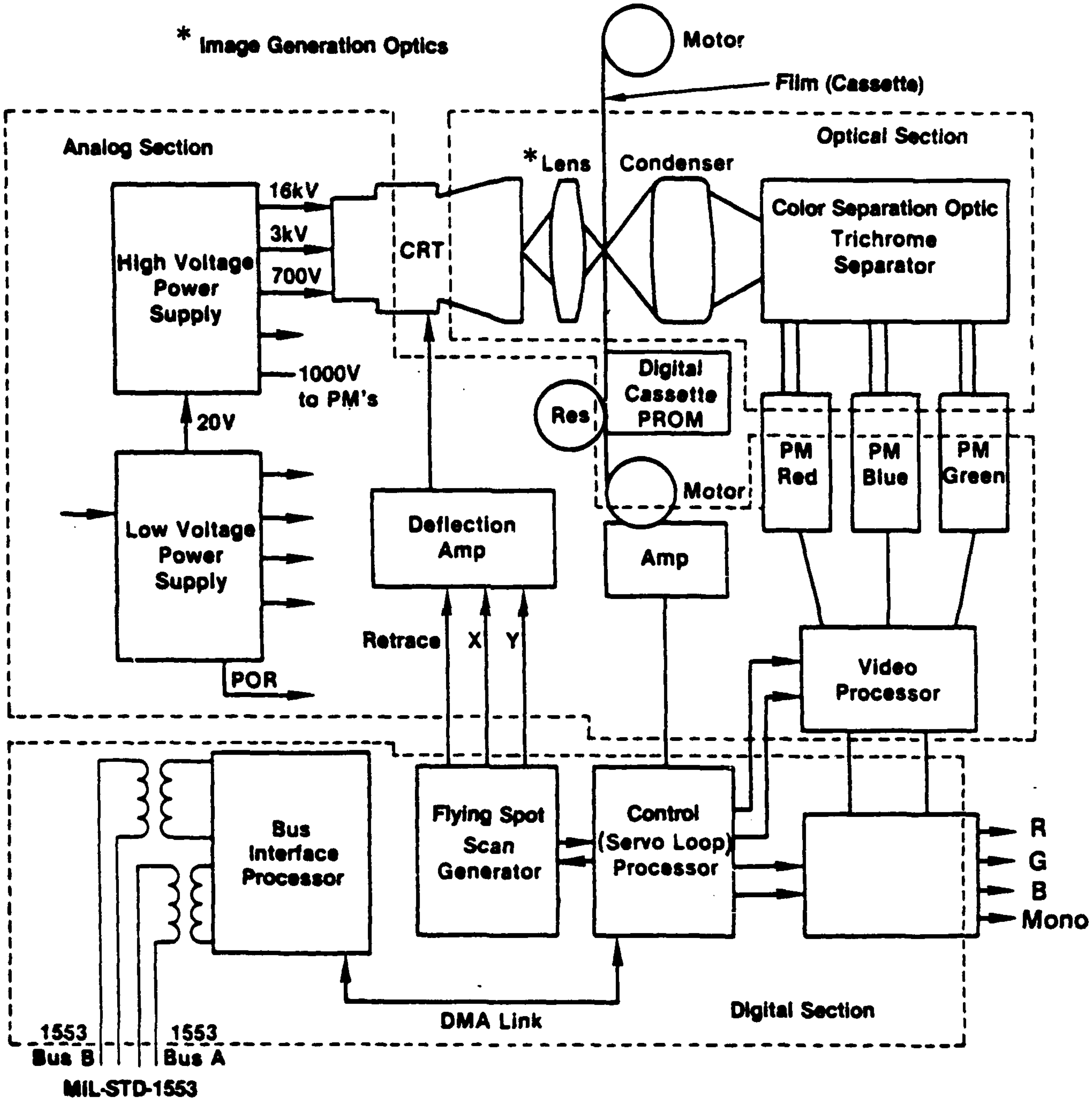


Fig. 2. RMR Block Diagram

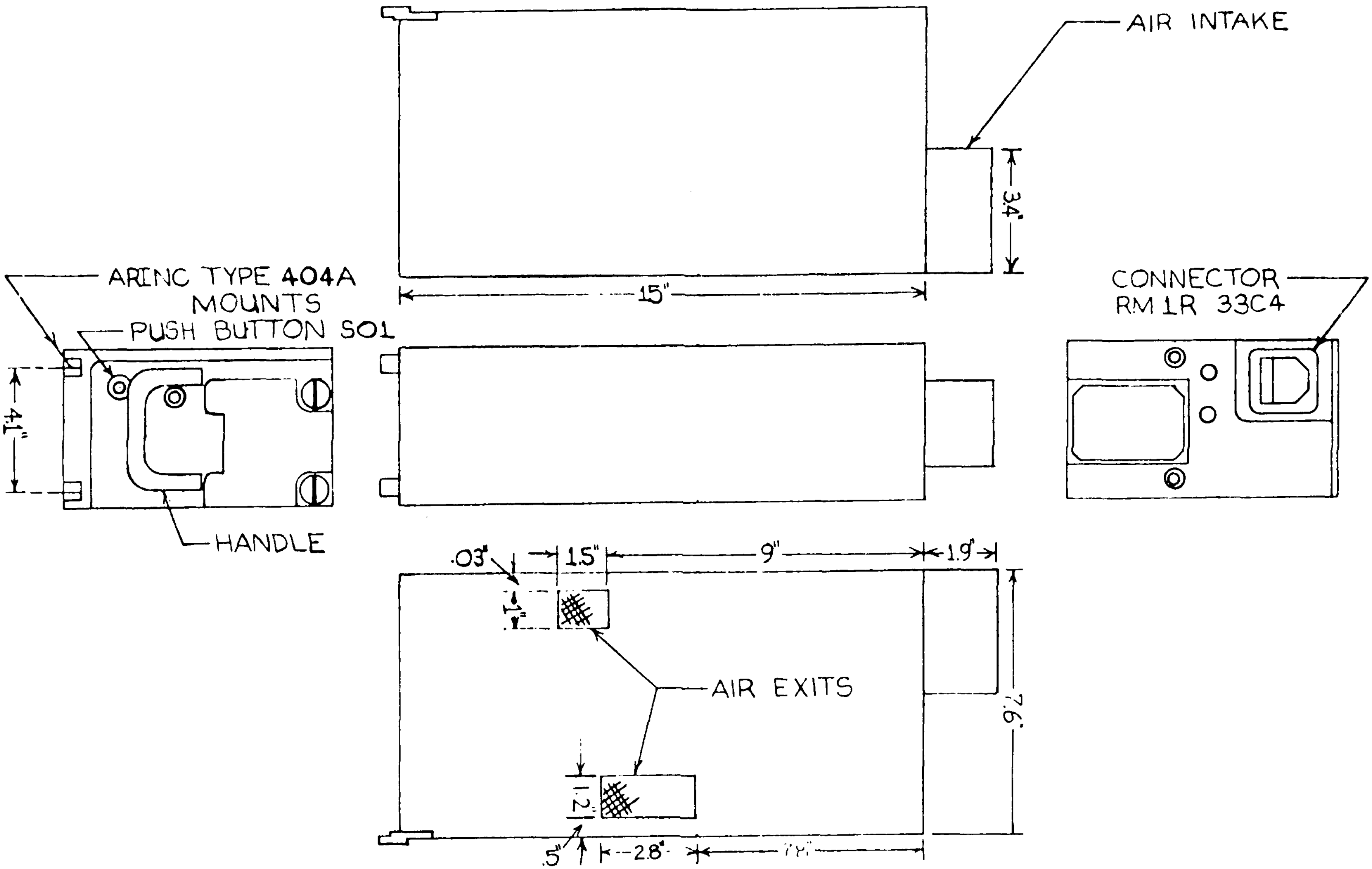


Fig. 3. RMR Dimensions

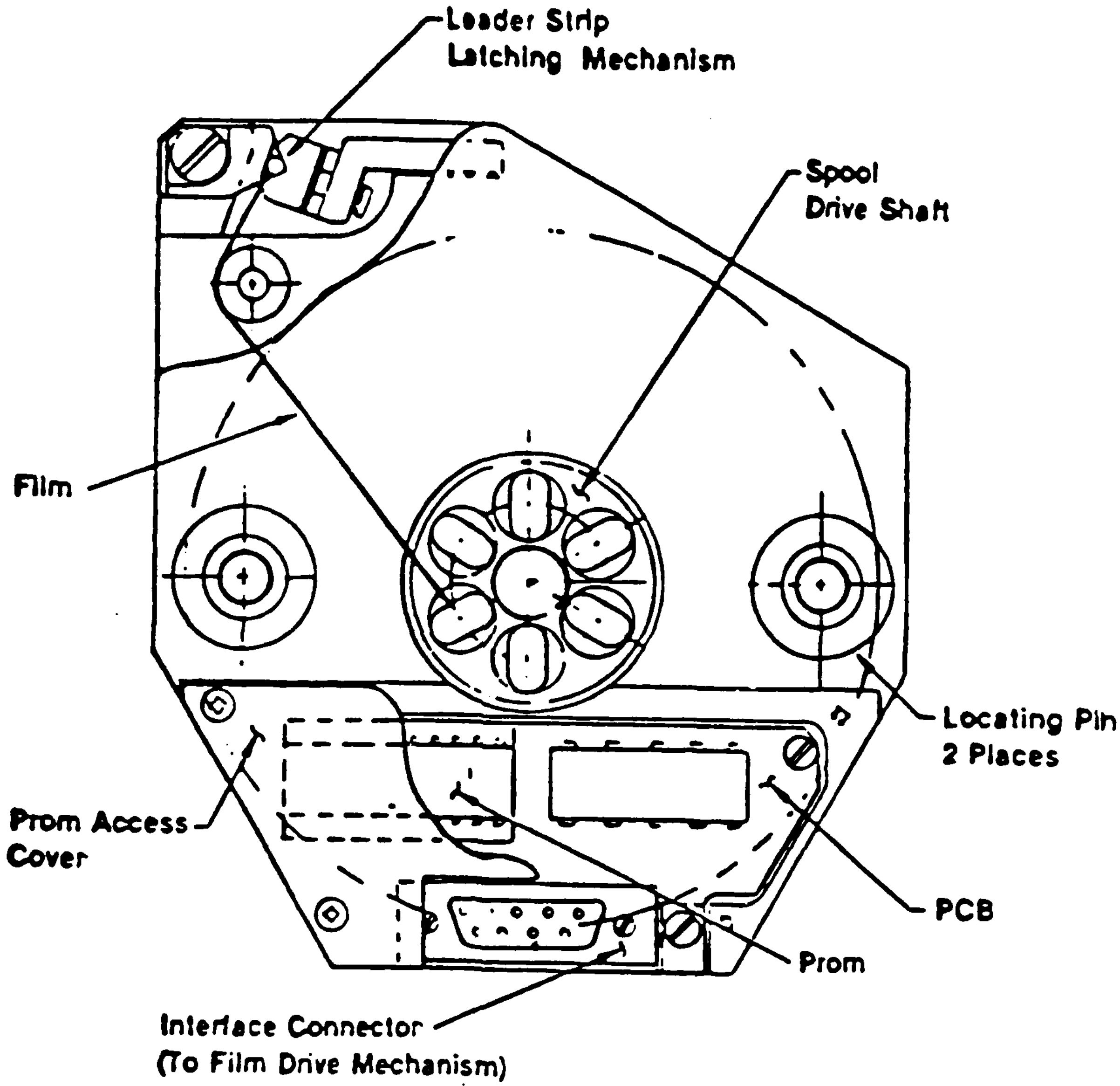


Fig. 4. PMR Cassette

During the evaluation of the RMR, it became clear that both this RMR and the one being built by Bendix for the HH-60 were unable to provide good color renditon of very dark areas on the maps. This was particularly noticeable on 1:250,000 scale maps, where mountains are heavily shaded to show elevation and cities are colored purple. In these areas, it was impossible to read black lettering which was written over the dark shading. Improvements to the RMR were investigated but judged to be impractical owing to inherent limitations in brightness and dynamic range of the FSS. DMA investigated several ways to brighten the filmstrips. One method considered was to print the paper charts with lighter colors of ink, but since this would have required that changes be made to well-established printing standards and approval by the many other users of DMA paper charts, it was rejected. A different film type and photographic process was tested in March 1985; this process produced copies with less density in the dark colors and produced much better pictures from the RMR. The filmstrip produced on the original type-2483 film was used in the initial lab tests and the simulation, and the new, brighter version using type 5243 film for the negative and type 5384 for the prints was used in flight tests. When using the RMR to view gray shade patterns on the film, 14 shades of gray are visible on the new film, while only 8 are visible on the old film.

The filmstrip used in this evaluation, designated as FS-100, was made by DMA to meet the needs of both the HH-60A helicopter test programs and the RMR evaluation. DMA was unwilling to produce two different test filmstrips on the short schedule required because of their already heavy workload of producing F-18 filmstrips of most of the world. Fortunately a combination of the HH-60A test sites and FWETE RMR test sites on one filmstrip containing 15 blocks (see figure 5) was feasiable.

Each roll of film contains maps equivalent to 560 sq ft of paper charts. The amount of coverage possible at one scale would be:

SCALE	COVERAGE
2 Million: 1	80 Million sq mi
1 "	20 " "
0.5 "	5 " "
250 Thousand: 1	1.25 " "
50 "	0.50 Thousand "

A typical filmstrip will contain smaller blocks of two or three scales. The geographic area and scales on a particular filmstrip will be completely determined by the user and included in the filmstrip requirement to DMA.

2.3 OPTICS

Optics within the RMR perform the following functions: a) Project the CRT raster onto the film, b) reduce the size of the CRT image on the film (de-magnify), c) separate the light which passes through the film into three color components, and d) redirect and couple the light into the PMTs. The optical train components, beam splitter, and wave-length characteristics are shown in figures 6, 7, and 8.

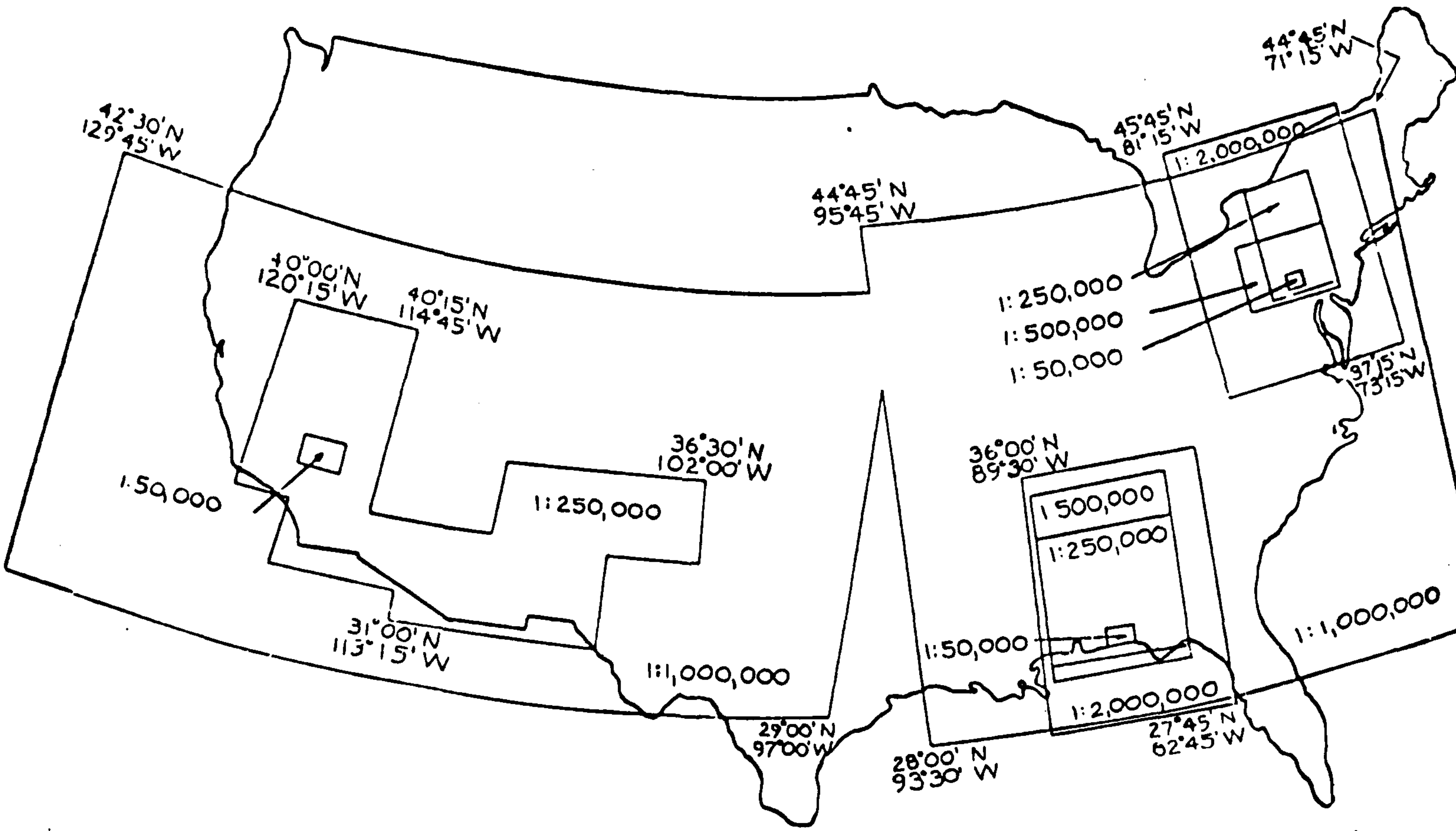


Fig. 5. FS-100 Coverage

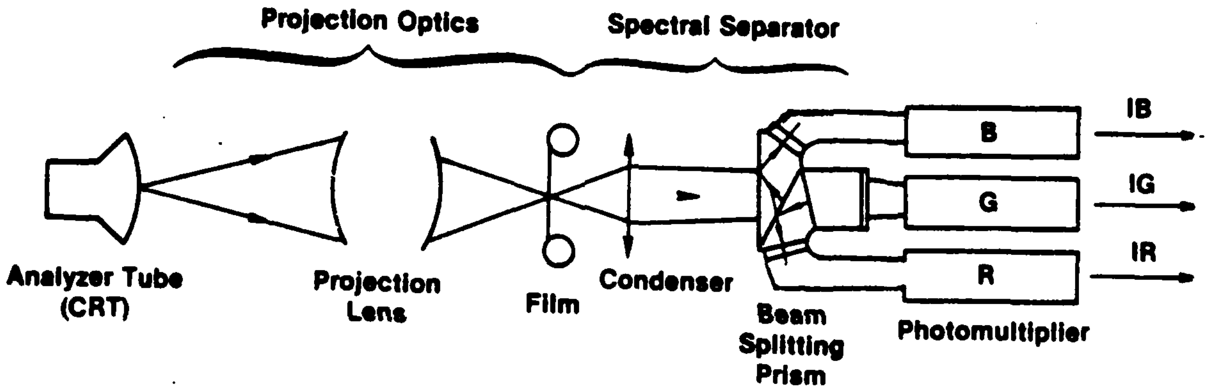
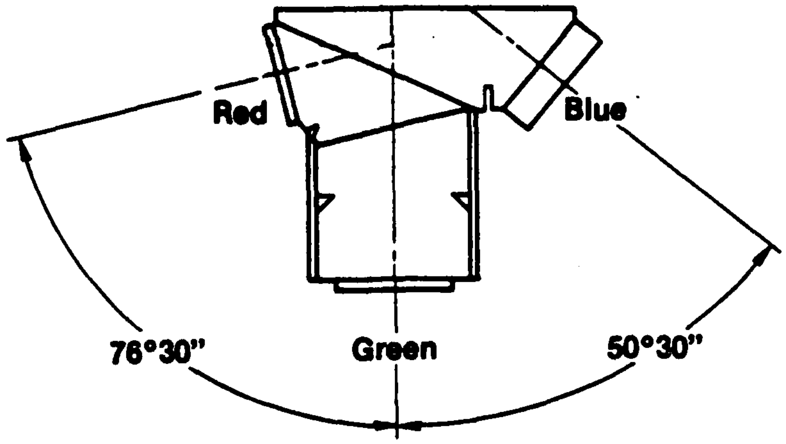


Fig. 6. Optical Train Components



BEAM SPLITTER PRISM ASSEMBLY

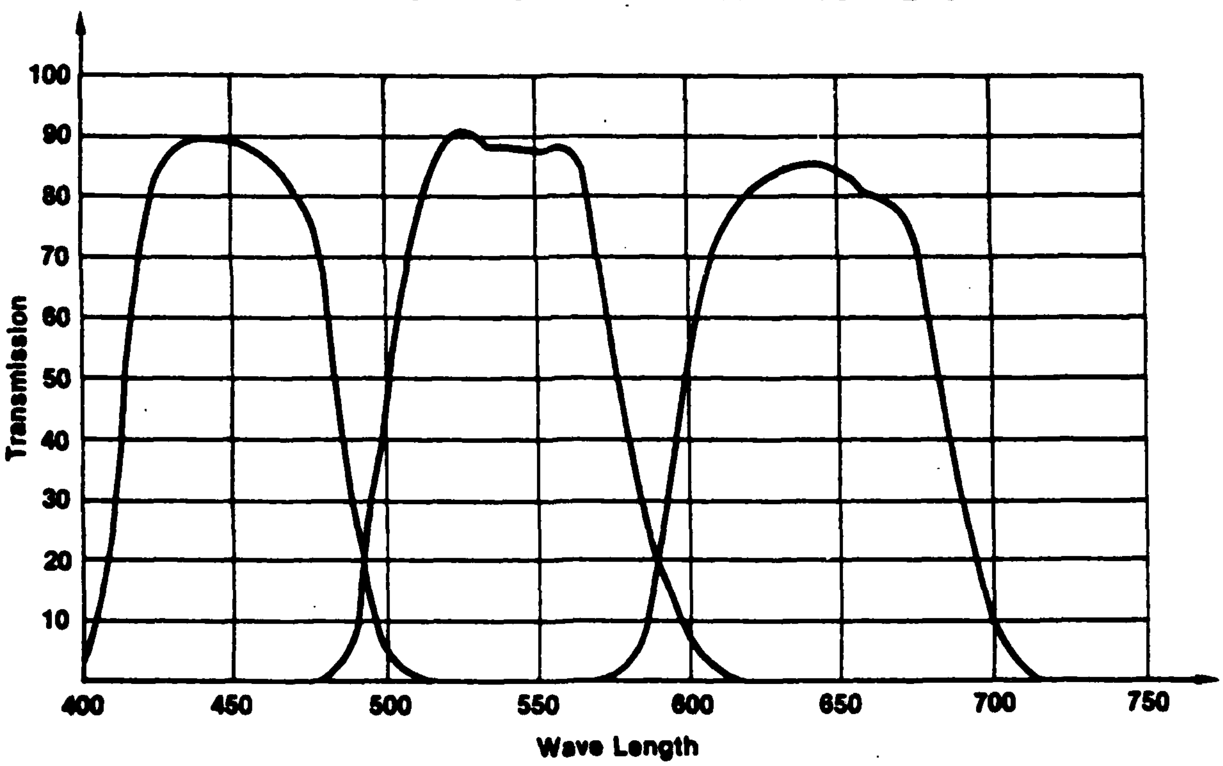


Fig. 8. Spectral Characteristics of Beam-Splitting Prism

The projection lens is fairly conventional. It focuses the raster from the CRT onto the film and demagnifies it. The demagnification factor allows the generation of a higher resolution raster on the film, since it allows the image (and spot size) on the CRT to be larger.

The condenser and beam splitter collect the light coming through the film and seperate it into three colors (Red, Green and Blue). Seperation is achieved by use of dichroic coatings on the reflective surfaces of the prism. There are also tuning filters to achieve accurate color balance. This system is more efficient than the alternative method of simply dividing the beam into thirds and filtering each beam. The greater efficiency allows lower CRT brightness requirements and/or a better signal-to-noise ratio out of the PMTs.

This system requires a tightly controlled, high-resolution CRT spot to be focussed on the film, but there are no resolution or accuracy requirements on the condenser, beam splitter, fiber optics and photomultiplier. The light beam, or flux, is captured, sensed and used as the video output; it is the time relationship between this signal and the position of the spot on the FSS CRT which determines the makeup of the image to be recreated on the video display.

2.4 FILM TRANSPORT

The film is rolled and unrolled by two motors which drive the film spool in the RMR and the film spool in the cassette directly. They are controlled by the microprocessor under digital closed-loop control. The control loop maintains tension on the film and translates the film by generating unequal torque commands to the motors. Feedback is provided by a resolver which engages the film sprocket holes and provides a precise readout of film position to the processor. DMA photographs the filmstrips in exact registration with the sprocket holes; so use of the sprocket holes as a reference in the RMR provides the best accuracy.

2.5 PROCESSORS

The system uses two motorola 6809 microprocessors. One, called the GAI (French Acronym) performs interface functions and certain system control functions. It controls the MIL-STD-1553B dual digital data bus interface. The second processor, called the GAS, performs the servoing, symbology generation, syncronization and sweep generation for the FSS.

2.6 INTERFACES

The RMR has a MIL-STD-1553B interface, which provides a standard way for it to receive data from the aircraft navigation system and send its Built-In Test (BIT) status back to the aircraft computer. The RMRs built for the Mirage 2000 have a different, unique data bus, so it was necessary for Thomson CSF to design and build the 1553 interface specifically for the units sold to the USAF. The RMR also has a simple RS-422 bus interface, which allows control of the unit by less sophisticated control units.

In addition, there is an RS-232 interface which allows direct access into the RMR's memory by a standard computer terminal. This interface is very useful for trouble-shooting problems and was used extensively during development of the unit and it's software.

2.7 MEMORY

The program memory for the RMR microprocessors is contained in two Ultraviolet Eraseable Programmable Read Only Memories (EPROMs), one for each processor. They are type-27128, 16K by 8 bits, and provide more than adequate and easily changed storage for the system's software.

The RMR also has two X-2212 Non-Volatile RAM's (NVRAMs). One is mounted on the motherboard and stores constants related to the particular units such as alignment correction numbers. The other is located on the GAS board and stores operating parameters such as mode, Elapsed Time Indicator (ETI), and power on/off cycle counter.

The NVRAM is a rather unusual chip in that it contains both a working RAM and an electrically eraseable prom (EEPROM). It is set up such that information loaded into the RAM during normal operation is automatically loaded into the EEPROM at power down. The EEPROM holds the data while power is removed from the unit and loads it back into the RAM at power up. This allows the unit to "remember" things such as elapsed operation time, even though the unit is turned off, just as it would if it used the more traditional core memory. Placing the ETI function in software eliminates the need for the electromechanical ETI and makes the ETI reading accessible to the software so it may be displayed on the screen during BIT.

2.8 CASSETTE

Film for the RMR is contained in a single spool cassette. The cassette is made up of several machined metal parts and carries a 5389 PROM (2K by 4) containing the filmstrip identification data. This data is arranged according to the rules in DMA specification PS/IDA/150 and gives location, size, etc., of each of the map blocks on the strip. The cassette is therefore self-indexing, i.e., when it is plugged into the RMR, a pair of connectors mate which allows the RMR processor to read the filmstrip data from the PROM.

2.9 POWER SUPPLIES

The low-voltage power supply is a modern switching supply which efficiently converts the incoming 28-VDC power to the various regulated DC voltages needed by the electronics. The high-voltage supplies are contained within the sealed optics module and provide the high voltages needed by the CRT and the PMT's.

2.10 HAMILTON STANDARD DESIGN

During the course of the FWETE RMR project, Hamilton Standard of Farmington, Connecticut decided to build RMR's for the avionics market. They arranged a licensing contract with Thomson CSF whereby Thomson provided the design of the RMR to Hamilton Standard and provided the services of their technical specialists to assist in modifying the design to be competitive in the US market. Hamilton Standard has now built prototypes of this new design and are actively competing for map display projects. Hamilton Standard's design is fundamentally the same as that described above. Significant differences in the hardware are:

a. Hamilton Standard's unit is a 3/4 ATR short size which has about 20% more volume than Thomson's, but is shorter and more compatible with the space available in several US aircraft.

b. Hamilton Standard designed in more extensive Built-In-Test (BIT) to meet the high levels of fault detection and isolation specified on current contracts.

c. Changes to the hardware were made to improve modularity (maintainability), make it easier to manufacture, and use more standard parts.

d. Processor architecture and software are based on US military standards.

e. Primary power supply is 115 VAC, 400 Hz, rather than 28 VDC.

f. It is intended for use with forced-air cooling and therefore has no fan.

g. It uses cold plate design (heat exchanger) to prevent cooling air (and contaminants) from passing over the circuit components.

3.0 LAB EVALUATION

The first phase of testing on the RMR consisted of tests which could be run in the electronics lab at building 485, WPAFB. The goal was to evaluate the performance, technology level, and usefulness of the RMR as far as practical before the simulation and flight tests were started.

3.1 RESOLUTION

Resolution of the RMR determines how sharp or fuzzy the picture will appear. It is limited by the technology used, including film, FSS CRT, optics, video amplifiers, and (independent of the RMR) the video display. Visual observations during all of our tests indicated that resolution was adequate for most tasks but limited for others and should be improved, if possible. For example, locations of roads, rivers, airports, etc., were as clearly visible on the display as they are on a map, but very small numbers and letters such as state highway numbers and names of small towns were often unreadable. An end-to-end test of system resolution, or modulation transfer as a function of frequency, was made by commanding the RMR to the location of the resolution test pattern on the test filmstrip, then measuring modulation in the output signal with an oscilloscope. These data are represented in figure 9. It shows that at 350 TV lines (half cycles) per picture width, the modulation is approximately 10%. The data were taken with used film on an RMR which had accumulated several hundred hours of operating time without realignment or cleaning, so the data should be representative of the performance available in the field, rather than that available under ideal lab conditions. Thomson CSF has demonstrated better resolution in lab tests.

3.2 ACCURACY

Positioning accuracy was measured at over a hundred different latitude and longitude points on various scales. This data is presented in figure 10. Evaluation of various data points indicated that on the average the mean error was less than 1% of screen width. A significant part of measured error is caused by paper map and/or filmstrip errors. For example; at least one way point (black-D-19) was found to be at measurably different lat.-long. locations on the different scales, while the map reader was positioning the film accurately according to the lat.-long. grids visible on the screen.

3.3 SYMBOLOGY

The RMR provides a built-in symbology generation capability, which allows the aircraft symbol, range ring, heading, time, scale and switch labels to be overlayed in-raster on the video image taken from the film. The symbols were bright, clear, and precise, but the original set of switch labels which we chose and had Thomson program into the RMR was unacceptable, as discussed in the simulation test report.

RESOLUTION DATA TAKEN USING AN OSCILLOSCOPE TO MEASURE MODULATION IN VIDEO SIGNAL OUTPUT FROM RMR SNO2. THIS DATA WAS TAKEN USING FILMSTRIP FS-100, BRIGHT TYPE FILM, TEST PATTERN NUMBER 2. BASED ON THE SCALE FACTORS IN USE ON THIS RMR, THE TEST PATTERN EQUIVALENCES ARE AS FOLLOWS:

1.25 = 250 TVL/PIC
23%

1.1 = 220 TVL/PIC
29%

1.0 = 200 TVL/PIC
MEASURED MODULATION = 38% OF MODULATION AT VERY LOW FREQUENCY

1.4 = 280 TVL/PIC
19%

1.6 = 320 TVL/PIC
14%

1.8 = 360 TVL/PIC
9.5%

2.0 = 400 TVL/PIC
VISIBLE MODULATIONS ≈ TO NOISE LEVEL

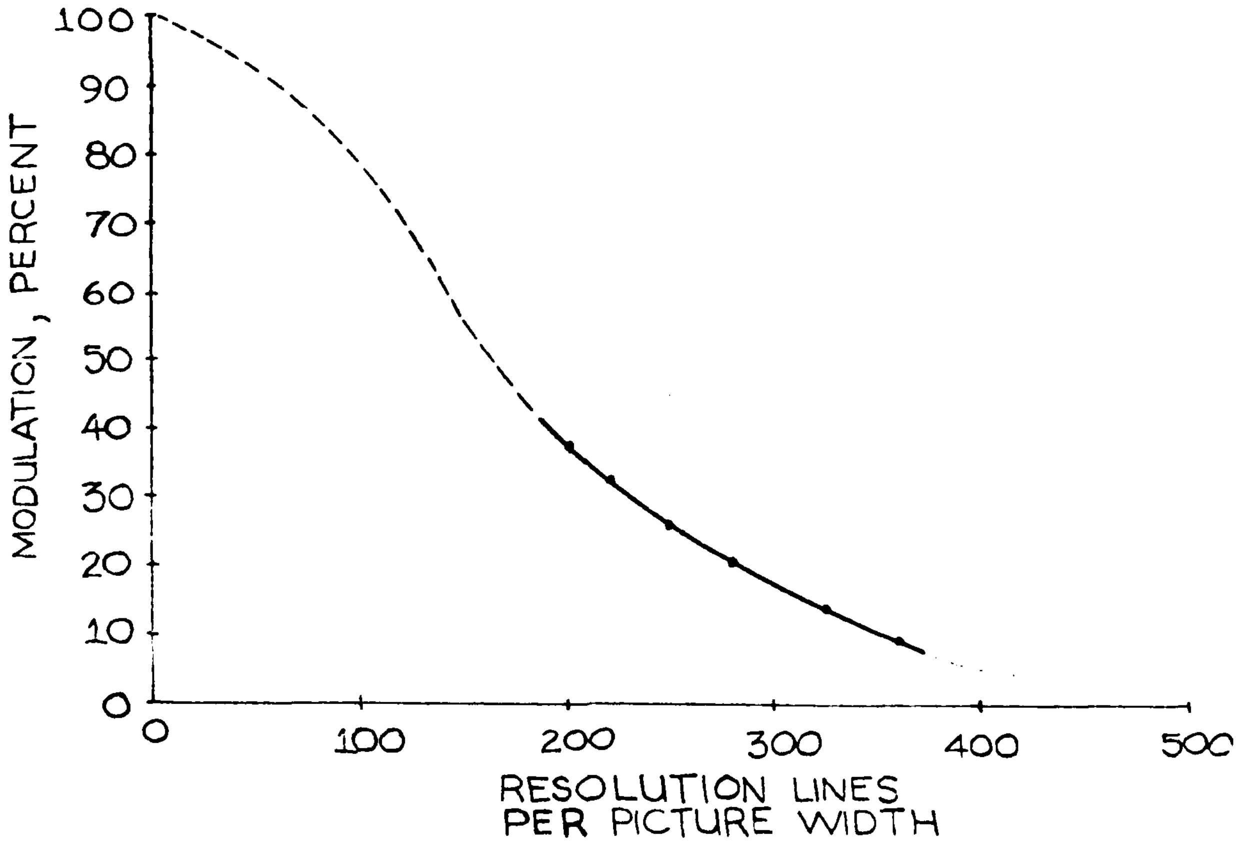


Fig. 9. Modulation Transfer Function

Positioning Error Data

			1:2M	1:1M	1:500	1:250	1:50
FS-100	Up	Mean	1.35 %	0.00 %	0.76 %	-0.32 %	-0.27 %
14 March 1985	Down	Std Dev	1.09 %	1.72 %	1.03 %	1.66 %	1.12 %
All 15 Blocks	Left	Mean	-0.78 %	-1.69 %	-0.14 %	-1.70 %	-2.17 %
	Right	Std Dev	0.78 %	4.14 %	1.16 %	1.19 %	0.98 %
FS-100	Up	Mean	0.73 %	0.45 %	-0.11 %	0.19 %	No
14 March 1985	Down	Std Dev	2.08 %	2.10 %	1.77 %	2.39 %	Points
Waypoints	Left	Mean	-0.53 %	-2.55 %	-1.15 %	-0.71 %	No
	Right	Std Dev	1.49 %	1.52 %	1.36 %	2.02 %	Points
FS-100	Up	Mean	-0.15 %	0.91 %	0.51 %	0.49 %	1.25 %
15 April 1985	Down	Std Dev	1.14 %	0.84 %	0.88 %	0.49 %	1.50 %
Waypoints	Left	Mean	0.44 %	0.91 %	0.10 %	0.52 %	0.63 %
	Right	Std Dev	0.97 %	1.01 %	0.75 %	1.44 %	0.88 %
FS-99	Up	Mean	-0.04 %	-0.35 %	0.51 %	0.14 %	-1.19 %
15 May 1985	Down	Std Dev	1.38 %	2.05 %	1.08 %	0.97 %	5.00 %
Test Points	Left	Mean	-0.71 %	-1.12 %	-0.92 %	-1.11 %	-0.75 %
	Right	Std Dev	0.49 %	0.25 %	0.60 %	0.56 %	3.11 %

Notes:

1. Units are percent of screen size.
2. Positive numbers indicate map displaced up or to the right of correct location.
3. Measurements represent an end to end system error, including interface, film, processing, data gathering, and mechanical positioning errors.

Fig. 10. Accuracy Data

Thomson promptly changed the software to provide a much better set of control labels and modes (see figure 11). In the currently planned installation of RMRs into US Aircraft, (HH-60 and F-15E) the symbology overlay will be generated by the existing aircraft symbol generator and the symbol generator in the RMR will be used only as a backup and as a reference for testing.

3.4 VIDEO STANDARD

The RMR provides a composite video signal similar to that used in ordinary tv sets. The contract with Thomson included a requirement to change the design to provide US standard 525-line video rather than European standard 625-line. Measurements taken on the video levels and timing parameters are shown in figure 12. In changing the signal format, compromises were made to allow the RMR to be easily set to either standard via a single software command. While the signal is different than the US standard in several areas, it is sufficiently similar to allow the video to be directly compatible with most US display and recording equipment. One significant difference is the greater number of active raster lines provided by the RMR, which required that the vertical sweep of the SMA-10 be adjusted in order to see all of the RMR symbology.

3.5 SIMULATOR CONTROL BOX

Thomson provided a Simulator Control Box with the RMR, which is connected to the R5-422 bus and allows an operator to feed control commands to the RMR without going through the 1553 bus. This is very useful for lab demonstrations and simple tests, since our 1553 bus tester (Loral SBA-100) requires that commands be typed in the form of hexadecimal numbers. Throughout most of the tests, however, commands were sent over the 1553 bus because this accurately represented the way the commands would be received from the aircraft control interface. Also, the Simulation Control Box flexibility and reliability was not as great as that of the bus tester.

3.6 SOFTWARE

All major functions of the RMR, including interface, scanning, film servoing, symbol generation, and BIT testing are controlled by the assembly language software (actually firmware) contained in two ultraviolet EPROMS. It was developed using a Motorola Exorciser software development system. It consists of parts of the software in use in the Mirage 2000, and new modules written to meet U.S. interface, filmstrip format and symbology requirements.

The software was not thoroughly tested prior to delivery. Bugs were discovered in the software which allowed certain combinations of commands or sequences of modes to cause the processor to make mistakes or stop processing completely until power was turned off and back on. Most of these problems were corrected by Thomson during the course of the evaluation. Also, the software was not adequately protected against bad input data or transients. On several occasions, the Non-Volatile memory in the RMR became scrambled and had to be reloaded. Memory scrambles were caused by 1553 bus commands being transmitted with insufficient gap time between words in the simulator.

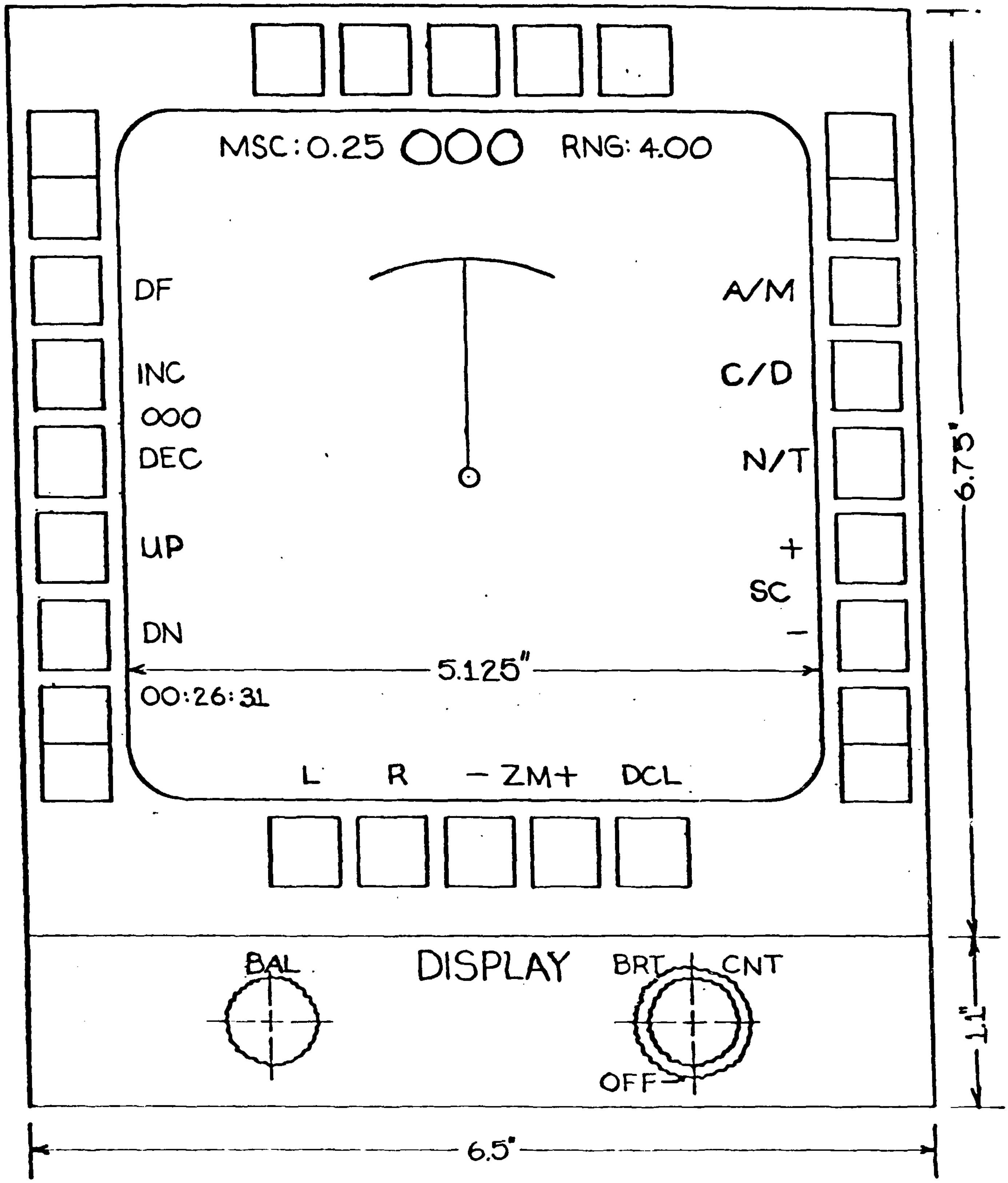


Fig. 11. Symbology

RMR Video Signal Comparison with NATO STANAG 3350 AVS

Item	STANAG 3350	RMR	
Waveform (percent of peak to peak signal)		Monochrome or Green	
(i) sync	-28.6%±5%	-5.5%	*-18.7%
(ii) blanking level	0 V	13.2%	* 0 V
(iii) reference black	5.4%±3.6%	13.2%	* 0 V
(iv) reference white	71.4%±10%	94.5%	* 81.3%
Nominal duration of line	63.5 us	63.3 us	
Line blanking period	10.9±0.2 us	12.7 us	
Interval between datum and back edge of line blanking period	9.4±0.1 us	8.0 us	
Front porch	1.5±0.1 us	4.7 us	
Line sync pulse	4.7±0.1 us	4.7 us	
Build up time (10-90%) of line sync pulses	< 0.1 us	0.6 us leading 0.1 us trailing	
Build up time (10-90%) of line blanking edge	< 0.1 us	0.095 us	
Equilization pulses			
(i) First sequence	6	None	
(ii) Second sequence	6	None	
Field sync pulses	6	None	
Number of active lines	485	512	

* Levels when DC bias is subtracted out

Fig. 12. Video Standard Measurements

CSF personnel corrected this problem the first time it occurred, and provided a procedure to allow USAF engineers to correct the problem.

3.7 DISPLAY PERFORMANCE

The color display is critical to any video map display system. All currently available color video displays use a shadow mask CRT as the display device. Resolution, contrast, and brightness of these CRTs is higher than that of commercial tv sets, but not as high as current monochrome airborne displays. Even if the RMR had perfect resolution, the color CRT would cause the image to be degraded.

Evaluation of the RMR requires the use of a color CRT display having a Red, Green and Blue interface (called R G B or non-composite color, as opposed to NTSC color). A high quality 17 inch Tektronix laboratory monitor was used for most of the lab tests. Our original plan was to use a prototype F-15 airborne color display unit (built by Bendix) for the flight test, since this unit was immediately available. However, this unit was too large to easily fit in the available space in the aircraft and had relatively poor video quality. A newer unit, (SMA-10) was also available and was chosen for use in the aircraft. Characteristics of this unit are shown in figure 13.

The shadow mask pitch or spacing between phospher triads on the SMA-10 is 0.012 inch. The spot size is on the order of 0.020 inch, which is the smallest size useable with a 0.012 inch shadow mask without color moire problems. This limits the resolution to approximately 50 line pairs per inch, or 500 lines per picture width (5 inch display) under optimum conditions. The SMA-10's demonstrated resolution under field conditions was approximately 400 lines.

The SMA-10 uses a high-performance directional contrast enhancement filter to improve viewability in sunshine. Luminance and contrast data from the SMA-10 are in figure 14. This data shows that contrast ratio is adequate for video display when the sun (light source) is more than about 45 degrees off axis of the display, but is very poor when the sun is directly over the pilot's shoulder. Angles of less than 15 degrees are generally blocked by the pilot's head and the seat back. These contrast capabilities correlate very well with pilot comments on the flight test video tapes, which indicate that the display looked good in moderate light (under heavy clouds), was useable under full sun conditions, and became unuseable at critical angles where the sun just came over the pilot's shoulder.

The display's axis was aimed slightly below the pilot's eyes, which is ideal since it prevents the pilot from seeing specular reflections of the sun or bright clouds on the front surface of the filter.

The peak luminance output of the display through the filter was about 60 footlamberts. This does not meet the normal criteria of 100 footlamberts minimum for a sunshine readable display. The image appears dim in sunshine and requires a finite amount of time for eyes to adjust when transitioning from looking at the outside scene (up to 10K footlamberts), to looking at the display.

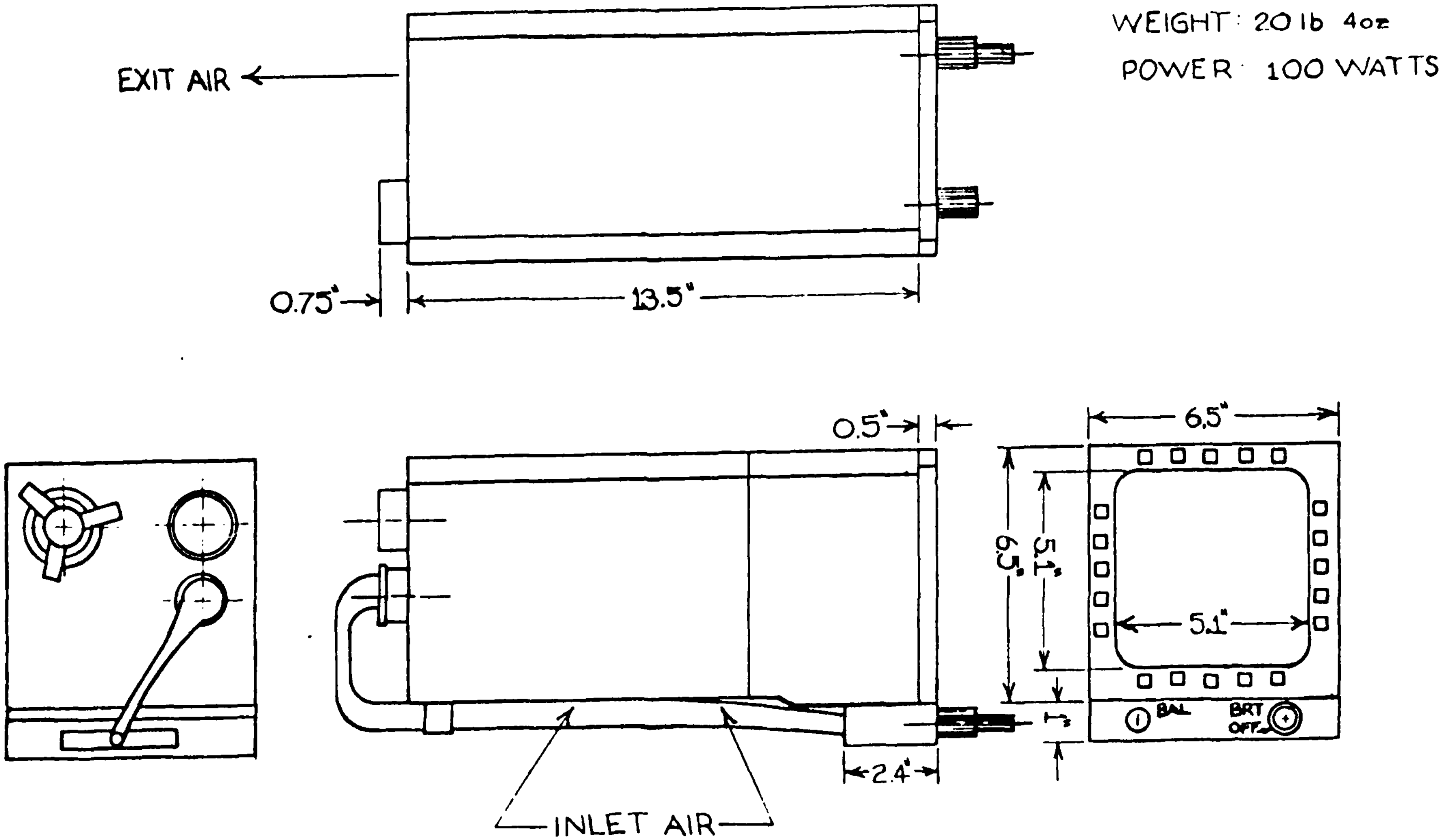
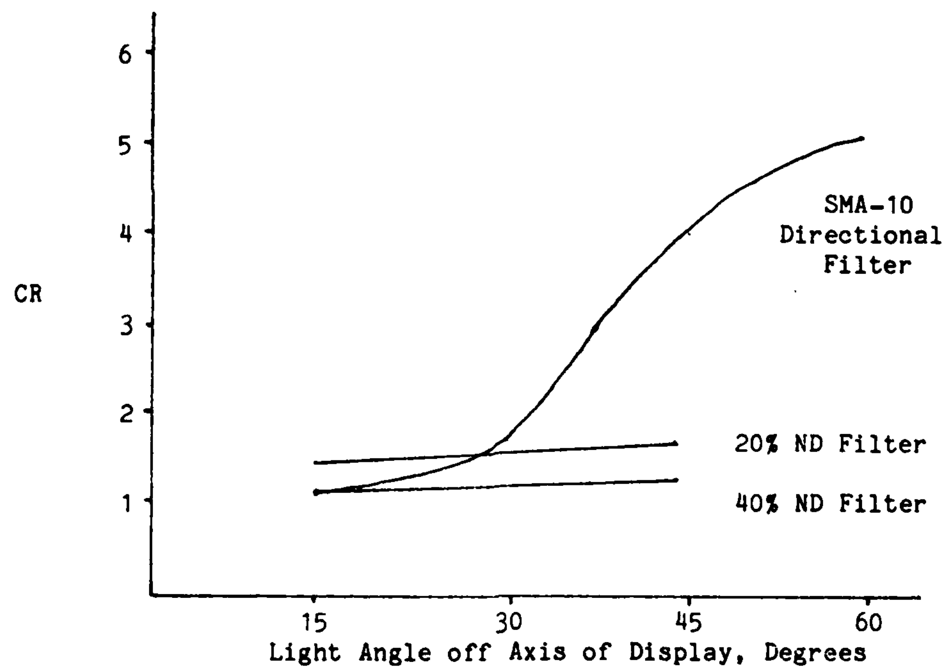


Fig. 13. SMA-10 Dimensions

SMA-10 Raster Luminance with Bendix directional filter
and VII color bar pattern input, room ambient

	Wht	Yel	Cyn	Grn	Pur	Red	Blu	Blk
maximum bright and maximum contrast settings	156	38	98	99	30	22	6.9	2.0
adjusted for maximum contrast	110	74	73	70	16	11.3	3.7	0.5
set for "white " whites (green signal level reduced)	62	33	25	22	17	13	3.4	0.4



Notes:
1. Maximum luminance on map reader video through filter was approximately 60 foot lamberts in flight test.
2. 20% and 40% Neutral Density (ND) filters shown for comparison.
3. Filters were not bonded to the CRT.
4. CR = Contrast Ratio = $(L_s+L_b)/L_b$.

Fig. 14. SMA-10 Luminance and Contrast

The image also appears to lack contrast under these conditions, even though laboratory measurements indicate that contrast is very good, since scattered light and limited instantaneous dynamic range in the eye will prevent one from perceiving very "black" blacks in the sunny environment.

3.8 RELIABILITY

Failure and operating time data was collected during the lab tests in an effort to make a qualitative assessment of the RMR's reliability.

During the initial delivery/acceptance testing in November 1984, the green video output from one RMR failed. The unit was returned to France, where the problem was traced to a solder bridge, or splash of solder, which short-circuited the PMT output during thermal transients. This failure was therefore considered an assembly workmanship defect.

In January 1985, SN02 failed. The problem was traced to noise spikes on the output of the film position resolver which caused the processor to make mistakes in counting sprocket holes to determine film position. The unit was returned to France and the resolver was replaced.

A third incident occurred at Eglin AFB during aircraft integration, when the RMR was again found to be positioning the film incorrectly. This problem was traced to a loose screw in the same resolver that had been replaced, so this problem is also judged to be a workmanship defect.

A fourth failure occurred on SN 01 late in the flight test. During three daytime flights, the map image began flashing and eventually went black after about 1/2 hour of flight. It appeared to get worse under high-temperature conditions. The problem was eventually traced to incorrect balance adjustment in the photodiode circuit which drives the PMT automatic gain control.

The two units accumulated on the order of 600 working hours and 700 power up/power-down cycles during the lab and simulation tests.

3.9 MAINTAINABILITY

Maintainability was also assessed on a qualitative basis during the evaluation. A key ingredient in easy maintenance is the use of Built-In-Test (BIT). The RMR performs both an initiated BIT Test (at start-up and when commanded by the operator) and a continuous BIT while processing. The results are displayed in the output video and are also output on the digital data bus.

The Initiated BIT test results are displayed in the form of a block diagram, identifying each module within the RMR and showing it's test status as OK (Green), Failed (Red) or not testable due to other failures (Yellow). (See figure 15.) This presentation is generated by the same processing and symbol generation hardware that is used to generate the map presentation, and gives a clear and easy to understand readout of unit status. This information is overlaid on a film position test pattern during part of the test to give an evaluation of system accuracy and is presented in table form during start up.

The first failure which occurred during our test was easily detected by watching the BIT display, since there was no green in the map video and the Green PMT was indicating failed. Isolation was not easy, since it was not the PMT which had failed, but the circuit card it is connected to.

The second failure (noisy resolver) was not detected by the BIT, but showed up as offsets in longitude on the operating map display. This is because the resolver count is reset each time the BIT test is run and the counting errors only occurred during slewing from one film frame to another.

The third failure was detected by the BIT, since the alignment pattern was displayed with a longitude offset, but required additional manual checks to isolate.

The BIT displayed numerous false alarms throughout our testing. It is clearly susceptible to noise and/or incorrectly set tolerances. The frequency of false alarm failure indications when the RMR is operating normally is unacceptably high. A software bug which had caused most of the BIT false alarms during the flight test was found and corrected at the end of the evaluation.

The BIT was redesigned and improved in the Hamilton Standard version of the RMR, in order to meet the stringent requirements for detection, isolation, and false alarm rate of most current avionics specifications.

The mechanical design of the box also needs additional maintainability attention. One must remove 10 screws to gain access to the 3 main circuit boards, 22 additional screws to access the motherboard (where alignment constants are stored); and other modules must be removed to gain access to the PMTs and CRT. The box must also have scheduled maintenance to regularly purge the optics compartment with dry nitrogen in order to prevent high voltage arcing at high altitude.

The film cassette is not interlocked, therefore it is possible to pull it out without first rewinding the film, which results in damaged film.

3.10 FILM LOADING

Film cassettes are easily plugged into and out of the RMR, and carry their identifying data in an attached PROM, so no operator inputs are required. Loading new film into the cassette and burning a PROM requires 1 to 2 hours of work and makes use of a standard 35mm film splicer and a PROM programmer. The film and PROM data are provided by the Defense Mapping Agency (DMA). It is necessary to open the cassette, spool the 65 feet of film onto the cassette spool, and splice a special contractor-furnished leader onto the leading end. If this is a new filmstrip (rather than an updated version of the one already in the cassette) the PROM data must be typed into a standard PROM burner and loaded into a new PROM chip, which is then plugged into the cassette.

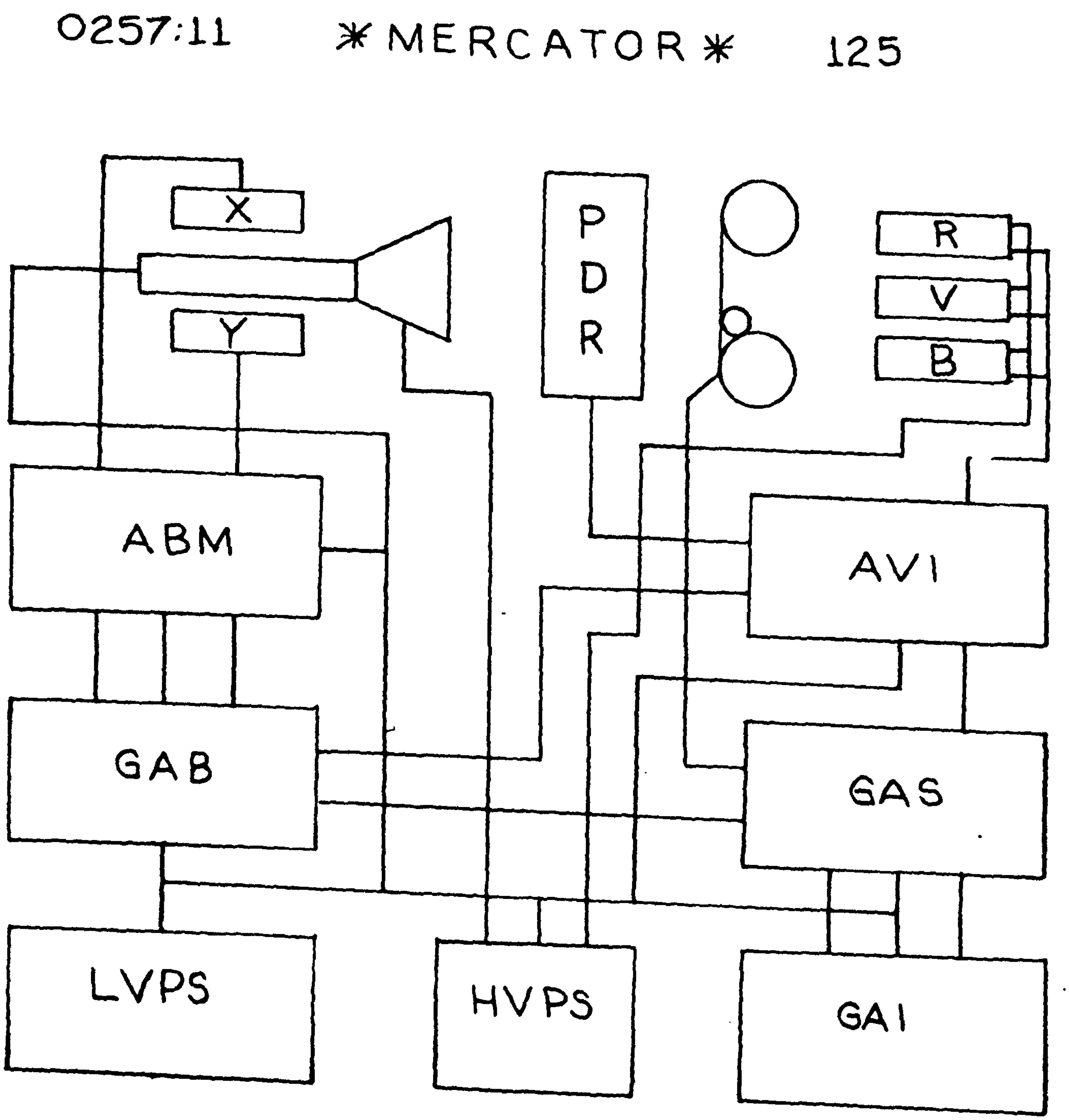


Fig. 15. BIT Reporting Format

4.0 EMI TEST

The RMR underwent EMI Testing in December 1984 and January 1985 to predict the equipments' performance in a more severe environment prior to flight test. The Electromagnetic compatibility and power branch (ENACE) performed both Radiated Emissions and Susceptibility (RE02, RS02) and the conducted Emissions and Susceptibility Tests. (CE03, CS01, CS02, CS06). The EMI Tests were performed to limits specified by MIL-STD-461 and 462 for Airborne Equipment.

The conducted and Radiated Emissions Tests showed the RMR to be emitting noise above the allowable standards at various frequencies. Based upon the recommendation of ENACE, an Electromagnetic compatibility (EMC) Safety-of-Flight (SOF) test was performed on the Aircraft prior to its first flight. The EMC SOF test showed no degradation of other systems on the aircraft.

The conducted and Radiated Susceptibility Tests showed the RMR to be susceptible to injection of noise onto +28 VDC power lines and radiated susceptibility onto the video lines. However, the RMR tests were conducted with non-aircraft cabling which could account for some of the problems. These suceptabilities were not seen in the aircraft.

The RMR Low voltage Power Supply (LVPS) fuse in the incoming 28-VDC line blew during startup in the CS01 and the CS06 tests. This was tentatively attributed to the transient suppression circuits within the LVPS absorbing an excessive current from the induced transient/AC voltage. Also, the RMR picture on the tv monitor showed noise bars during the RS02 test and the picture was lost during the 60 to 120-MHz scan. The problems were not considered severe because:

a) They only occurred at isolated frequencies,
b) The lab wiring did not accurately duplicate aircraft wiring,
c) These problems were not observed in the aircraft EMC test or flight test.

5.0 SIMULATION

A simulation was conducted using the RMR to provide a moving-map display in an F-16 simulator cockpit at the ASD/ENECH Crew Station Design Facility. It is described in detail in the report. It included 10 pilots and 10 missions, each 10 to 15 minutes long. Half of the missions were flown with the RMR and half were flown with a paper map. This installation used a 5" Collins color CRT display and had a stroke-written overlay of the flight plan. The RMR control buttons were arranged around the display periphery and were labelled in the RMR video. The arrangement and functional logic of the switches was found to be unacceptable during the simulation and was redesigned (see figure 11) prior to flight test. The simulation did not detect a significant improvement in the pilot's navigation performance when using the RMR, since the missions consisted of following the guidance provided by the navigation system. Most of the pilots favored the RMR over paper maps, and felt it would aid in terrain clearance and general navigation. Having the flight plan overlayed on the map in a variety of scales was considered very useful, since it allowed the pilot to have an up-to-the-minute "pictorial" display of where he was, where the navigation system was taking him, where his next waypoint or target was, etc.

6.0 FLIGHT TEST

The flight test was conducted by the 3246th Test Wing at Eglin AFB, Florida from 30 May to 19 September 1985. Eight and one half hours of productive RMR flight time was accumulated on seven flights. Several flight hours were also accumulated on other missions and the unit logged a total of 230 hours during flight testing. Two and three-fourth hours of the productive flight time was accumulated at night and most of the flights included some hard maneuvering (up to 5 G's) and low-level flying (500 ft.). The test plan is contained in Test Directive No. 921AEA17, titled "Electronic Color Map Reader and Display (ECMD) System."

The test was mainly a pilot appraisal of the RMR in a deep strike, low altitude, air to ground scenerio. The test demonstrated that the RMR can be most useful in this type mission where awareness of the terrain and situation around the pilot is of great importance and workload is high.

The test had nine stated objectives:

1. Appraise the usefulness of the map reader in target location and identification during low level operation.
2. Appraise the usefulness of the map reader in decisions to go over or around obstacles.
3. Appraise the usefulness of the map reader in reorientating the crew after aerobatic maneuvering at both low and high altitudes.
4. Appraise the usefulness of all the map scales, modes, and functions of the map reader.
5. Determine the accuracy of the map reader's response to the Inertial Navigation System (INS).
6. Assess the reliability of the map reader during normal flight and aerobatic maneuvering.
7. Appraise the effects of INS accuracy at all map scales and at high and low altitudes.
8. Appraise the workload caused by the map reader.
9. Appraise the aesthetic features of the map reader and display: video quality and readability; switch labeling, accessability and complexity.

The equipment was located and interconnected as shown in figure 16. All controls for the RMR and display were on the face of the display, as shown in figure 11. One copy of the filmstrip shown in figure 5 was used throughout the flight test. RMR Serial Number One (SN1) was used in all of the productive flights. SN2 worked correctly in the lab during the tests but failed, for unknown reasons, to operate when installed in the aircraft. The symbol generator within the RMR provided the symbols and switch labels seen on the display. In a production system, a symbol generator would generate the flight plan lines and other mission specific annotations on the map. Because of technical problems associated with installing a symbol generator capable of drawing flight plans in the flight test F-4E, the flight plans were drawn on the film instead.

The equipment installed on the aircraft included a data bus interface unit (DBIU) which was part of the aircraft modification necessary to install the RMR. It converted the binary INS information to a format compatible with the RMR's 1553 data bus and the ARN-101 instrumentation pod.

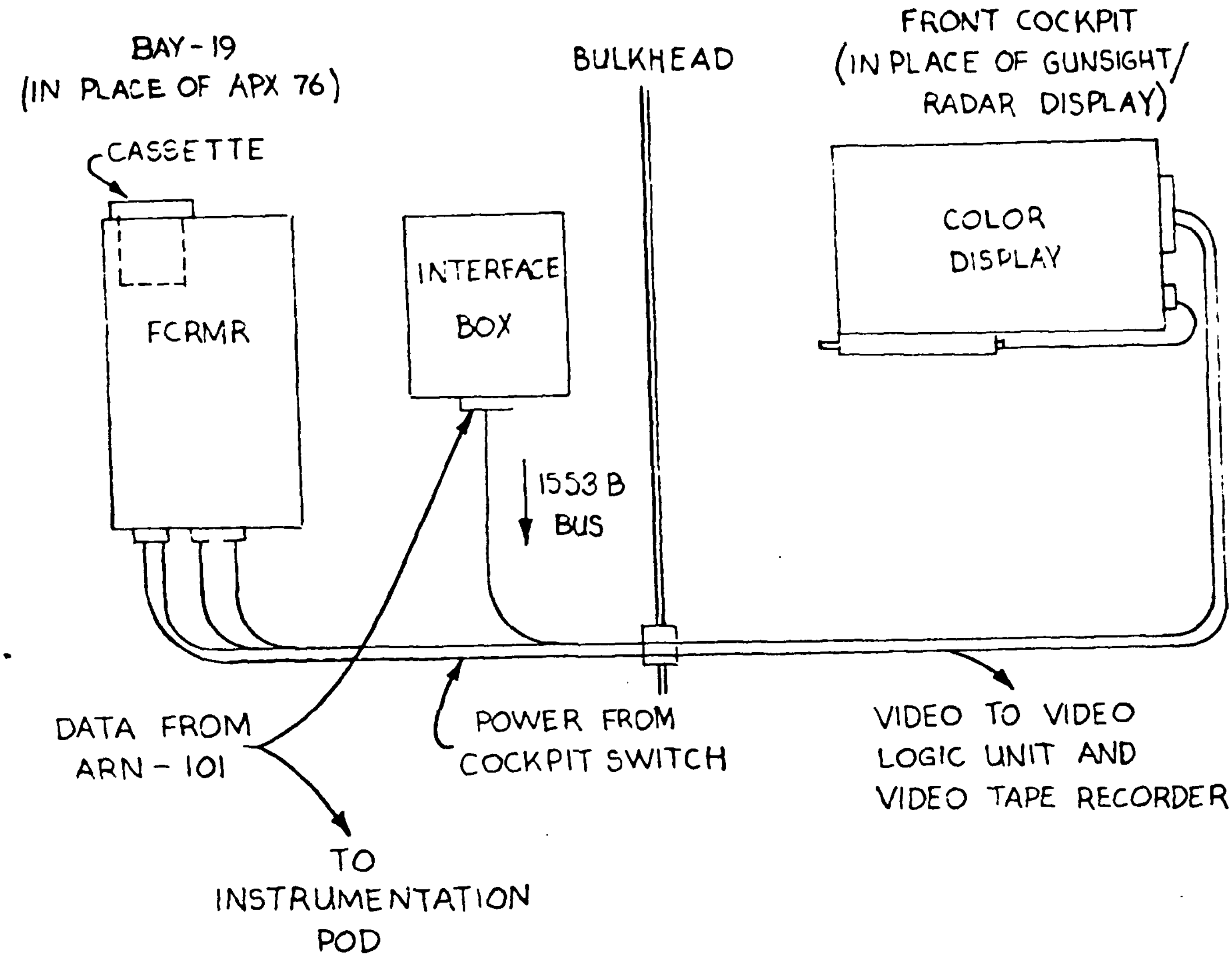


Fig. 16. Flight Test Configuration

A time code generator was also carried on board the F4 and was connected to both the ARN-101 instrumentation pod and the Airborne Video Tape Recorder (AVTR). After the mission, this single source of timekeeping allowed correlation of data between the cockpit video and audio recorded on the AVTR and the ARN-101 pod data. The ARN-101 pod records the digital data from the INS. The pod was carried on an inboard station under the right wing of the aircraft.

6.1 FLIGHT TEST QUESTIONAIRES

The pilots filled out a detailed questionaire after each mission. The questions and responses are summarized in figure 17. The following paragraphs include comments collected on the questionaires and/or derived from the video tapes.

6.2 FLIGHT TEST ACCURACY

The pilots were asked to assess accuracy and they documented numerous observations on the video tape by calling out when they crossed over waypoints, etc. The video tapes, which carry an IRIG time track, were also correlated with printouts of instrumentation pod data to compare the position shown by the RMR with the position commanded by the INS. Of numerous points checked, about 80% of the samples were within 1/16 inch of the correct position and all were within 1/4 inch on a 6-inch monitor. This data shows that the RMR achieved essentially the same accuracy in the air as it did in the lab (See paragraph 3.2). The INS error is generally much larger than the map reader errors. When pilots called out waypoints as they crossed them, there was frequently up to 1/8-inch error visible on the screen (represents up to 1/4 mile of INS error) on a 1:250K (8 mile) scale. Errors of this size are very obvious on the 1:50K scale (1/4 mile equals about 3/4 inch) but are not noticeable on the larger scales.

6.3 FLIGHT TEST RELIABILITY

The flight test included a qualitative assessment of equipment reliability. One confirmed hardware failure occurred on 25 March 85 when the resolver wheel became loose. This is part of the same resolver which failed during bench tests at WPAFB and the failure is attributed to poor workmanship during the first repair.

There were four different occasions when the film position resolver slipped relative to the film, and two occasions when the cassette failed to mate properly with the film leader. These problems required rethreading the film leader and realigning the resolver.

Several "software" failures occurred during the lab checkout of equipment and during checkout of the system on the aircraft prior to flight. These problems were corrected by reloading mode and alignment words in the RMR's non-volatile memory using a portable computer terminal.

Question No.		Poor	Fair	Rating Good	Excellent	N/A
1.	usefulness in/of: locating targets		1	4	2	
2.	identifying targets		3	3	1	
3.	deciding to gc over and/or around obstacles		4	3		
4.	reorientation: after hard turns at low alt.		1		5	1
5.	after aerobic maneu-vering at high altitude			1	1	5
6.	map scales; 1:50K		2	3	2	
7.	1:250K			3	4	
8.	1:500K		2	5		
9.	1:1M		2	5		
10.	1:2M		2	4		1
11.	modes: man. select	1	3	1		2
12.	zoom			3	4	
13.	DCL		1	3	1	2
14.	north up		2	3	2	
15.	track up		1	2	4	
16.	cent'd acft position		6	1		
17.	decentered			3	3	1
18.	auto/man.	1	1	3	1	1
19.	evaluate: video quality	1	4	2		
20.	switch labeling			5	2	
21.	switch accessability			2	5	
22.	change in workload due to the RMR	-50%	-25%	0%	+25%	+50%
		1	4		2	

Fig. 17 PILOT QUESTIONAIRE SUMMARY
Flights conducted on 27,28 Aug. and 9,11,13,16,17 Sept. 85

One flight was nonproductive because RMR SN02 refused to operate when turned on inflight. This problem disappeared when the unit was later operated in the lab. At this time, the source of the problem has not been found but the symptoms indicate that the film or cassette may have been jammed which prevented the unit from completing it's power-up built-in-test sequence.

On several flights near the end of the test, the display began flashing after about 1/2 hour of flight, and eventually the map image went black (symbols stayed bright). The same thing was observed on the video tapes in debriefing, showing that the problem was in the RMR and not in the display. Three main circuit boards in the RMR were replaced by the ones in the spare unit, but this did not correct the problem and it returned on a later flight. This problem was isolated to an imbalance in the adjustment of the PMT AGC photodetector circuit after the flight test was completed.

The flights included low-altitude, high speed operation and hard maneuvering (up to 5 G's). The RMR and display performance was not affected by these environments.

The display experienced two hardware failures during our testing, both related to the fact that the display's circuit boards are heavily modified prototypes. These failures were not relevant to the evaluation of the Thomson RMR but they did cause major schedule delays because spare parts and documentation were not quickly available.

6.4 FILM SCRATCHING

The filmstrips used in the flight test experienced approximately 10 to 15 hours of operating time in the air, including use on training missions, and about 230 hours use altogether. By the end of the flight tests, several scratches were visible in the map image. The scratches ran along the entire length of the filmstrip, which indicated that there were edges or irregularities in the film guides, cassette, or leader connecting parts that caused this. None of the pilots mentioned the scratches in debriefing which indicated that they were not causing any problem in the aircraft. The scratches are visible on the display as 3 or 4 parallel east-west lines. Thomson CSF indicated that they have modified the film guide design to prevent this on later units.

6.5 MAP JUMPING

During most of the test flights, the map image had an intermittent "jump" or "flinch." This occurred on an apparently random basis and normally showed up as a displacement of the map image for from 1/2 second to 1 minute, sometimes occuring as often as every few seconds or not occurring at all for up to 5 minutes. The displacement was frequently to the south about 1/2 to 5 miles. This was very objectionable on the 1:50K scale map since it showed up as large motions on the screen. The displacement was proportionately smaller on the other scales.

Erratic data were found in the INS instrumentation recordings which indicated that the data coming from the aircraft to the RMR had discontinuities which account for some of the jumps. The discontinuities in the navagation data could also account for the incidents in which the RMR appeared to be searching back and forth along the filmstrip; it was merely trying to go to a commanded position which happened to be on a different film frame, then returning to the frame where it started out when correct data was again received. Detailed analysis of instrumentation data and correlation with video tapes revealed that there are some jumps in the RMR video which do not correlate to discontinuities in the data, indicating that the RMR was also generating discontinuities on it's own. A separate problem observed throughout our tests was a slight east-west "rocking" of the map. This is related to the film-positioning servo loop not being completely stable under certain combinations of film position and friction, and was later corrected when the French engineers adjusted a software coefficient.

6.6 VIDEO QUALITY

The Bendix SMA-10 display with directional filter (see section 3.7) was used, in place of the HUD/radar display, as a temporary installation to display the color map video. Although the display evaluations indicate that this unit has brightness and contrast better than other airborne color displays, all of the pilots who flew the system on sunny days with the sun directly over their shoulder (within the cone of acceptance of the directional filter) complained that the display was not bright enough and looked "washed out" in sunshine. They were always able to see large objects and large, black lettering on the screen but had difficulty seeing small details and color changes under sunny conditions.

The resolution available in the aircraft was inadequate to see very small details such as state highway numbers and names of small towns, regardless of brightness, and degraded slightly further when the display was operated at maximum brightness. Visual comparison of resolution patterns and video in the aircraft with that observed in the lab indicates that it was roughly the same as that documented in sections 3.1 and 3.7. The display could not be turned down dim enough for proper use at night. Pilots who flew at night said it was too bright and, when attempting to turn it down, they occasionally turned it off by accident due to the soft switch detent (all the test pilots and engineers inadvertently did this). The display was turned off for night landings and other maneuvers requiring good out-of-cockpit vision for safety. Lab adjustments of the display before the flight tests were aimed at achieving maximum brightness for visibility in sunshine. It is clear from this data that color CRT's for production aircraft must have better low-level brightness control and color tracking than this (see section 3.7). Pilots also stated a need for lighting around the bezel switches to make them easier to find at night. On both night flights, the pilots accidently pressed wrong buttons.

6.7 MAP SCALE

Several pilots stated a preference for the 1:250K map scale (8 miles per display height) for low-level navigation and air-to-ground attack. Some liked the 1:50K scale when they were in the target area because it shows such great detail. They dislike the fact that they do not gain much situational awareness when only a small area (1.6 miles) is displayed in this scale but this can only be resolved by using a larger display unit. Pilots also expressed the need for a pointer showing the best way to return to the flight plan. This became clear when a pilot performed severe evasive maneuvers on the 1:250K scale and, when he decided to return to the flight plan, only a small portion of the flight plan was visible on the edge of the display. The 1:500K scale was used occasionally. The 1:500k, 1:1M, and 1:2M scales were referred to as "good for large area navigation" but the 1:1M and 1:2M scales were used very little during the flights. One pilot found the ECMR especially useful when relocating the target in thick haze after having broken off an attack. He did this by placing the flight vector on the target, then holding his heading as he looked straight ahead for the target (his comment: "this is neat!"). While the "scale +" and "scale -" buttons worked correctly and were far superior to the "rotary" implementation used in simulation, there was still some confusion about which scale would come up if a button was pushed. One suggestion was to use the scale of the next available map, in miles per screen height (like a radar scale) as the label, instead of the "+" and "-".

7.0 CONCLUSIONS

1. The RMR used modern digital electronics and high performance analog film scanning technology roughly equivalent to that currently in production in the U.S.

2. The RMR accuracy is consistent with the state of the art for film scanning and positioning equipment and suitable for basic navigation and orientation functions. Resolution (sharpness) of the picture is marginally adequate.

3. The reliability of the hardware is resonably good for prototype/preproduction units. The software does not have adequate safeguards to make it immune to bad input data and transients.

4. The BIT and maintainability design show a good approach and intent but would require numerous refinements to be acceptable for current USAF operations.

5. The value of a color moving map in fighter missions was again demonstrated. Providing the map in the form of a video on a CRT display i easily implimentable, especially on aircraft which have modern navigation and display systems.

6. The adequacy of current color CRTs for display of color raster video in the full sunshine environment of a fighter aircraft was demonstrated to be marginal.

7. Use of filmstrips of existing paper maps as a data base for a moving map display system is adequate in the critical areas of data base availability and compactness of storage, but is not compatible with desired refinements. These include: a) Provide precise terrain elevation data for use in terrain perspective view displays, navigation and terrain following systems, b) provide selective declutter of features from display and, c) provide higher contrast and more saturated colors in the color video signal to help overcome the contrast limitations of color CRT displays.

8. The goal of procuring production hardware from foreign sources without incurring full development costs was partially achieved. Hamilton Standard has obtained a license to use this technology in their U.S. built RMR and are currently competing on a fairly equal basis with U.S. designs on DoD procurements.

REFERENCES

The following technical data is retained in ASD/ENASI. Some of these documents are limited to government distribution since they contain proprietary data.

1. Mercator GAI Software Technical Description, AVG DOC/ST. No. 141/84

2. Mercator RMR Environmental Qualification Results, AVG/NCO No. 69/84

3. Acceptance Test Procedure, AVG/NCO No. 61/84

4. Acceptance Test Reports, AVG/NCO No. 61/84

5. Mercator RMR Controls and Control Functions and Maintenance Instructions, AVG/NCO No. 73/84

6. RMR Schematic Diagrams, one set

7. RMR Operating and Maintenance Instructions, ENASI-85-1

8. RMR logbook, September 84 to September 85

9. Defense Mapping Agency Remote Map Reader Filmstrip Specification, PS/IDA/150

10. Bendix Technical Summary, SMA-10 Shadow Mask Color Display Unit

11. Aircraft Instrumentation Wiring Schematic, 84XEE0126

12. Mod Power Distribution Schematic, 81XEE0069

13. Request for Test and Class II Modification Data for the FWETE Full Color Remote Map Reader, Revised 1 Aug. 84

14. Test Directive No. 921AEA17, 28 Feb. 85

15. Hamilton Standard RMR description

16. Human Factors Evaluation of the Thomson CSF Color Remote Map Reader (ENECH Simulation)

17. Flight test data including all questionaires and video tapes of all missions

18. FCRMR EMI Test Results, dated April 1985

LIST OF ABBREVIATIONS

ASD ..... Aeronautical Systems Division
BIT ..... Built In Test
CCD ..... Charge Coupled Device
CMR ..... Color Map Reader
CRT ..... Cathode Ray Tube
DAC ..... Digital to Analog Converter
DDTE .... Director Defense Test and Evaluation
DMA ..... Defense Mapping Agency
DMAAC ... Defense Mapping Agency Aerospace Center
DoD ..... Department of Defense
EEPROM .. Electrically Eraseable Programmable Read Only Memory
EMI ..... Electromagnetic Interference
EMC ..... Electromagnetic Compatability
EPROM ... Eraseable Programmable Read Only Memory
ETI ..... Elapsed Time Indicator
FCRMR ... Full Color Remote Map Reader
FSS ..... Flying Spot Scanner
FWETE ... Foreign Weapons, Equipment, and Technology Evaluation
GPS ..... Global Positioning System
HVPS .... High Voltage Power Supply
INS ..... Inertial Navigation System
IPT ..... International Programs and Technology
LRCA .... Long Range Combat Aircraft
LRU ..... Line Replaceable Unit
LVPS .... Low Voltage Power Supply
NATO .... North Atlantic Treaty Organization
NTSC .... National Television System Committee
NVRAM ... Non-Volitile Random Access Memory
OUSDRE .. Office of the Under Secretary of Defense Research and Engineering
PCB ..... Printed Circuit Board
PE ...... Program Element
PMT ..... Photomultiplier Tube
PROM .... Programmable Read Only Memory
RAM ..... Random Access Memory
RDTE .... Research, Development Test and Evaluation
RGB ..... Red Green Blue
RMR ..... Remote Map Reader
USAF .... United States Air Force
WPAFB ... Wright Patterson Air Force Base

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5-86